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DN 134:196222
TI Fatigue-resistant steel sheets for materials which undergo blanking
IN Hasegawa, Morihiro; Hiramatsu, Akifumi; Iihara, Katsuyuki; Omosako, Koji; Jufuku, Hiroyuki; Kabutodani, Shoichi
PA Nisshin Steel Co., Ltd., Japan
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AB The steel sheets contain **C** 0.3-0.8, **Si** ≤3.0, **Mn** ≤1.5, **Cr** ≤2.0, **Cu** ≤0.5, N 0.0005-0.02, O 0.0005-0.01, P ≤0.02, S ≤0.01, acid-soluble Al 0.01-0.1 weight%, and balance **Fe** and show the spheroidization rate of carbides 50-95%, average size of spheroidal carbides ≤0.3 μm, and hardness 200-400 HV. The steel sheets may also contain **Mo** 0.1-2.0, **Ni** 0.1-3.0, V 0.01-0.5, Ti 0.01-0.1, Nb 0.01-0.2, and/or B 0.0005-0.01 weight%. The steel sheets show good fatigue resistance even after blanking and refining to have hardness ≥45 HRC (Rockwell **C** hardness), and are useful for machinery parts, etc.

PATENT ABSTRACTS OF JAPAN

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(54) STEEL SHEET FOR PUNCHED PARTS EXCELLENT IN FATIGUE CHARACTERISTICS

(57)Abstract:

PROBLEM TO BE SOLVED: To produce a steel sheet for punched parts excellent in fatigue characteristics and usable even in the case of being refined to ≥45HRC after punching.

SOLUTION: This steel sheet for punched parts contains, by weight, 0.3 to 0.8% C, ≤3.0% Si, ≤1.5% Mn, ≤2.0% Cr, ≤0.5% Cu, 0.0005 to 0.02% N, 0.0005 to 0.01% O, ≤0.02% P, ≤0.01% S and 0.01 to 0.1% acid soluble Al, in which the spheroidizing ratio of carbides is 50 to 95%, the average grain size of spheroidal carbides is ≤0.3 μm, and the hardness thereof is 200 to 400 HV. Moreover, it may contain one or ≥ two kinds among 0.1 to 2.0% Mo, 0.1 to 3.0% Ni, 0.01 to 0.5% V, 0.01 to 0.1% Ti, 0.01 to 0.2% Nb and 0.0005 to 0.01% B.

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CLAIMS

[Claim(s)]
[Claim 1] C: 0.3 - 0.8 % of the weight, Si: 3.0 or less % of the weight, Mn: Less than [Cr:2.0 % of the weight], less than [Cu:0.5 % of the weight], N:0.0005 - 0.02 % of the weight, O:0.0005 - 0.01 % of the weight, P:0.02 % of the weight or less, S:0.01 % of the weight or less, and acid soluble aluminum:0.01-0.1 % of the weight are included 1.5 or less % of the weight. The steel plate for blanking components with which the remainder had the presentation of Fe substantially and the rate of balling-up of carbide excelled [mean particle diameter / of balling-up carbide] in the fatigue property characterized by 0.3 micrometers or less and hardness being 200 - 400HV 50 to 95%.
[Claim 2] Furthermore, the steel plate for blanking components excellent in the fatigue property containing Mo:0.1-2.0 % of the weight, nickel:0.1-3.0 % of the weight, V:0.01 - 0.5 % of the weight, Ti:0.01-0.1 % of the weight, Nb:0.01-0.2 % of the weight, and B:0.0005 - 0.01% of the weight of one sort, or two sorts or more according to claim 1.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention can carry out a temper to the high intensity of 45 or more HRCs in heat treatment after blanking processing, and relates to the steel plate used as various machine parts, such as a cutter, a tool, and a gearing, etc.
[0002]
[Description of the Prior Art] As a steel plate used for various machine parts etc., after piercing steel materials to a part shape, there are some a temper is carried out [some] by heat treatment. There are a high degree of hardness, high intensity, high toughness, high fatigue strength, abrasion resistance, etc. in the mechanical property required of this kind of components. A fatigue property and abrasion resistance improve by generally raising hardness and reinforcement. However, toughness falls with the rise of hardness or reinforcement and the defect resulting from especially the rise of notch susceptibility actualizes.
[0003] Notch susceptibility is ingredient physical properties which show generating inclinations, such as a crack on the basis of surface discontinuity etc., and fracture. Although the fracture surface is exposed to a steel-materials end face in the usual blanking processing, it is carried into a product, without removing completely surface discontinuity, such as a minute crack which exists in the fracture surface. The surface discontinuity which exists in the components end face after a punch acts as a notch or an initial crack, and becomes the cause which makes notch susceptibility of components high. Especially, in order to attain high intensity-ization of components, in 45 or more HRCs or tensile strength, with the steel materials raised to 1500 or more MPas, notch susceptibility becomes still higher and fatigue strength and toughness tend to fall temper hardness. the time of being based on the approach of creating components by machining, the approach of carrying out grinding of the end face of blanking components by machining, etc. -- a blanking side -- the effect of description is cancelable. However, these approaches have low productivity and are not suitable for components manufacture of a complicated configuration. Although it is also possible to remove the effect of a blanking side by polish, time amount and cost start by the grinding method. the blanking side in mass-production-method Rhine industrial from such a thing -- the guarantee of description is very difficult.
[0004]
[Problem(s) to be Solved by the Invention] The fracture surface becomes the origin of fatigue breaking among the fracture surface which constitutes a blanking side, and a shear plane. then, the thing for which the rate of a shear plane is raised -- piercing -- a field -- the method of improving description is adopted partly (JP,8-337843,A). Although the rate of a shear plane is raised even to 100% by fine blanking, use of the elasticity-ized ingredient is needed for the improvement of fine-blanking nature (JP,5-14764,B). However, since productivity and the yield are low as compared with the usual blanking, fine blanking is inapplicable to manufacture of

cheap components from profit in many cases. Although the effect elasticity-ization affects the rise of the rate of a shear plane produces the usual blanking similarly, with the elasticity-ized ingredient, burr is large and the display flatness of the pierced components becomes low. There is a limitation in the improvement of this point and the blanking nature by elasticity-izing. The fall of components on the strength is also effective in an improvement of notch susceptibility. However, since fatigue strength also falls with a fall on the strength, the property required of various machine parts is not acquired.

[0005] Thus, it is difficult to raise a fatigue property, securing the reinforcement of blanking components, and it very difficult to pierce with the hardness level of 45 or more HRCs, and to improve the fatigue property of components especially. Furthermore, as a steel plate for blanking components, it is also required the components with which it heat-treats after a punch, and to excel in hardenability, the toughness after heat treatment, etc. from a certain thing. By being thought out that such a problem should be solved and combining the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and balling-up carbide under specific conditions, this invention is excellent in a fatigue property, and even if it carries out a temper to 45 or more HRCs after blanking processing, it aims at offering the usable steel plate for blanking components.

[0006]

[Means for Solving the Problem] In order that the steel plate for blanking components of this invention may attain the purpose, C: 0.3 - 0.8 % of the weight, Si: 3.0 or less % of the weight, Mn: Less than [Cr:2.0 % of the weight], less than [Cu:0.5 % of the weight], N:0.0005 - 0.02 % of the weight, O:0.0005 - 0.01 % of the weight, P:0.02 % of the weight or less, S:0.01 % of the weight or less, and acid soluble aluminum:0.01-0.1 % of the weight are included 1.5 or less % of the weight. The remainder has the presentation of Fe substantially and the rate of balling-up of carbide is characterized by the mean particle diameter of balling-up carbide being [0.3 micrometers or less and hardness] 200 - 400HV 50 to 95%. This steel plate for blanking components can contain Mo:0.1-2.0 % of the weight, nickel:0.1-3.0 % of the weight, V:0.01 - 0.5 % of the weight, Ti:0.01-0.1 % of the weight, Nb:0.01-0.2 % of the weight, and B:0.0005 - 0.01% of the weight of one sort, or two sorts or more further.

[0007]

[Function] in order that this invention person etc. may suppress the effect the description of the fracture surface affects a fatigue property on the assumption that the fracture surface is generated in a blanking side to the minimum -- a blanking side -- investigation examination of the relation between description and a fatigue property was carried out at the detail. Consequently, when the ingredient which enlarged balling-up carbide and elasticity-ized it was pierced, while the rate of a shear plane of a blanking side became high, it found out that the dimension of the void in the minute crack and directly under [fracture surface] was large. [in the fracture surface] On the other hand, when carbide was made small and a certain amount of hardness was given to steel materials, it solved that the minute crack and void used as the origin of fatigue breaking were stopped to the minimum.

[0008] The effect the magnitude of carbide affects a minute crack and a void is considered as follows. Although the trace with which carbide was dragged by the local plastic deformation at the time of blanking remains near the fracture surface, extent of a trace differs according to the magnitude of carbide, and the minute crack by which a big and rough void and a big and rough void gathered and grew arises in an organization with big and rough carbide. Moreover, the steel materials of elasticity [migration length / of the carbide dragged at the time of blanking] become long, and a void and a minute crack become large according to the die length of migration length. It is necessary to carry out the temper of the steel materials to a certain amount of hardness, and to control the migration length of carbide at this point. Although the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and

balling-up carbide are combined under specific conditions by this invention by using the above knowledge as the base, it explains for every requirements below.
[0009] It is the fundamental alloy content which affects the reinforcement and the toughness of the C:0.3 - 0.8 % of the weight steel materials of quality governings, and in order to obtain the hardness of 45 or more HRCs, 0.3 % of the weight or more is needed. however, the void which the amount of increment ****** carbide of C content increases, and originates in carbide is quantitative -- and it becomes large in size. Moreover, in C content exceeding 0.8 % of the weight, a cementite deposits in a grain boundary and toughness and fatigue strength worsen. C content of an excessive amount is MS. The fall of strength, toughness, and a fatigue property is caused for the generation inclination of retained austenite by the fall of a point.
Si: It is the alloy content added by molten steel as a deoxidizer 3.0 or less % of the weight, and raise hardenability and it is effective also as a solid-solution-strengthening element of a ferrite. The operation which delays a deposit of the carbide at the time of heat treatment is presented, and it also becomes the cause of producing internal oxidation directly under a steel-materials front face in the cases, such as hot-rolling, annealing, and heat treatment. Moreover, Si addition of an excessive amount makes steel materials hard, and enlarges the burden to blanking metal mold. In order to control these bad influences, the upper limit of Si content was set up to 3.0% of the weight. In addition, since deoxidation of molten steel is compensated of other components, such as Mn and aluminum, it can also consider as Si additive-free fundamentally.
[0010] Mn: It is the alloy content added by molten steel as a deoxidizer 1.5 or less % of the weight, and act effective also in improvement in hardenability. However, at the time of blanking, the nonmetallic inclusion of Mn system used as the origin of a void or a minute crack is generated, and the bad influence which causes the toughness fall by development of the band structure is also done. Moreover, Mn addition of an excessive amount makes steel materials hard, and enlarges the burden to blanking metal mold. In order to control these bad influences, the upper limit of Mn content was set up to 1.5% of the weight. In addition, since deoxidation of molten steel is compensated of other components, such as Si and aluminum, it can also consider as Mn additive-free fundamentally.
Cr: It is an alloy content effective in improvement in the reinforcement after 2.0 or less % of the weight hardenability and heat treatment, and toughness, and also present the operation which prevents graphitization during annealing. However, if Cr of the excessive amount exceeding 2.0 % of the weight is contained, while the fall of toughness will be seen on the contrary and balling-up annealing will become difficult, the manufacturability of an intermediate product also deteriorates. Cr addition of an excessive amount makes steel materials hard, and also enlarges the burden to blanking metal mold. Since hardenability, and the reinforcement and the toughness after heat treatment are suppliable with other alloy contents, it can also consider as Cr additive-free fundamentally.
[0011] Cu: It is an alloy content effective when improving the hardenability of steel materials, and the toughness after heat treatment like nickel 0.5 or less % of the weight. However, Cu addition of the excessive amount exceeding 0.5 % of the weight becomes the cause which causes hot shortness.
V, aluminum, Ti, Nb, etc. a nitride, and carbon nitride are formed N:0.0005 to 0.02% of the weight, it is the alloy content which presents the operation which makes an austenite grain detailed, and when compound addition is carried out with these elements, the effectiveness of N becomes remarkable with 0.0005% of the weight or more of a content. However, if N of the excessive amount exceeding 0.02 % of the weight is contained, detailed-ized effectiveness is not only saturated, but the bad influence to which toughness and a fatigue property are reduced on the contrary will appear.
[0012] O:0.0005 - 0.01-% of the weight aluminum 2O3 etc. -- it is the injurious ingredient which

forms nonmetallic inclusion. Nonmetallic inclusion may become the origin of a fatigue crack by the nonmetallic inclusion itself while becoming the origin of a void or a minute crack at the time of blanking. Moreover, since the toughness after hardening / annealing was reduced and it had the bad influence also on the fatigue property, the upper limit of O content was set up to 0.01% of the weight. Although the lowest possible O content was desirable, since reduction of extreme O content made the manufacturing cost rise, the minimum of O content was set up to 0.0005% of the weight.

It is the injurious ingredient to which it segregates to the grain boundary P:0.02 or less % of the weight, and the toughness after hardening / annealing is reduced, and decreasing as much as possible is desirable. However, according to reduction of P content, a manufacturing cost becomes high. Then, the range which does not have a substantial bad influence on toughness degradation was investigated, and the upper limit of P content was set up to 0.02% of the weight.

[0013] It is the injurious ingredient which forms nonmetallic inclusion, such as MnS, S:0.01 or less % of the weight, and has a bad influence on the workability of steel materials, reinforcement, and toughness. MnS serves as an origin of a void or a minute crack at the time of blanking, and the MnS itself becomes the origin of a fatigue crack. Moreover, in the rolled stock by which MnS is spread by the rolling direction, plane anisotropy appears greatly in workability, reinforcement, and toughness. In order to control these bad influences, the upper limit of S content was set up to 0.01% of the weight.

Acid Meltable aluminum: 0.01 to 0.1% of the weight, aluminum is an effective alloy content as a deoxidizer, fix N in steel as AlN, and also present the operation which controls abnormality growth of austenite crystal grain at the time of heat treatment. These operations become remarkable at 0.01 % of the weight or more as acid meltable aluminum. However, the effectiveness of acid meltable aluminum is saturated with 0.1 % of the weight, and acid meltable aluminum of an excessive amount causes defective generating, such as a rise of a manufacturing cost, and a surface crack, on the contrary.

[0014] Mo: It is the alloy content added if needed 0.1 to 2.0% of the weight, and present the operation which raises hardenability, and the reinforcement and the toughness after heat treatment. Such effectiveness becomes remarkable with 0.1% of the weight or more of Mo content. However, if Mo of the excessive amount exceeding 2.0 % of the weight is contained, while toughness will fall on the contrary and balling-up annealing will become difficult, the manufacturability of an intermediate product deteriorates remarkably. Mo of an excessive amount makes steel materials hard remarkably, and also enlarges the burden to blanking metal mold.

nickel: It is the alloy content added if needed 0.1 to 3.0% of the weight, and present the operation which raises hardenability and the toughness after heat treatment. Moreover, since reinforcement and toughness improve by nickel addition, a fatigue property is also improved. Such effectiveness becomes remarkable with 0.1% of the weight or more of nickel content. The effectiveness of nickel which raises the reinforcement after heat treatment, toughness, and crack propagation resistance is saturated with 3.0 % of the weight, with nickel of the excessive amount exceeding 3.0 % of the weight, steel materials make it hard remarkably and the burden to blanking metal mold also becomes large.

[0015] It is the alloy content added if needed V:0.01 to 0.5% of the weight, and while forming carbide in steel and raising reinforcement and toughness, the operation which makes the old austenite crystal grain detailed and raises crack propagation resistance is presented. Although such an operation and effectiveness become remarkable with 0.01% of the weight or more of V content, reinforcement, toughness, and the effectiveness of raising crack propagation resistance are saturated with 0.5 % of the weight. If V of the excessive amount exceeding 0.5 % of the weight is contained, the manufacturability of an intermediate product will deteriorate

on the contrary.
Ti: It is the alloy content added if needed 0.01 to 0.1% of the weight, and form the carbon nitride which cannot dissolve easily at the time of heat treatment, control big and rough-ization of the austenite crystal grain at the time of hardening heating, and present the operation which raises crack propagation resistance. In compound addition with B, since N in steel is fixed as TiN, it works to also secure the amount of effective B. An operation of such Ti becomes remarkable at 0.01 % of the weight or more. However, Ti content of the excessive amount exceeding 0.1 % of the weight becomes the cause that a big and rough nitride is formed, and causes the fall of toughness.
[0016] Nb: It is the alloy content added if needed 0.01 to 0.2% of the weight, and form stable carbon nitride, control big and rough-ization of crystal grain like V and Ti at the time of hardening, and present the operation which prevents degradation of toughness. Such an operation becomes remarkable with 0.01% of the weight or more of Nb content. However, Nb of the excessive amount exceeding 0.2 % of the weight decreases the dissolution of carbide to a matrix, and causes a fall on the strength.
It is the alloy content added if needed B:0.0005 to 0.01% of the weight, and hardenability is raised, the segregation of P to the grain boundary is controlled, the grain boundary is strengthened, and the operation which prevents the toughness fall resulting from intergranular fracture is presented. Although such an operation becomes remarkable with 0.0005% of the weight or more of B content, it is saturated with 0.01 % of the weight. In addition, since the effectiveness of B addition will be spoiled if added B combines with N in steel and becomes Nitride BN, it is desirable to carry out compound addition of Ti which fixes N in steel as TiN on the occasion of B addition.
[0017] rate [of carbide] of balling-up: -- the gestalt of the mean-particle-diameter:0.3-micrometer or less carbide of 50 - 95%, and balling-up carbide -- the fracture surface of blanking workability and a blanking side -- it has big effect on description. The investigation and research by this invention person etc. showed that the magnitude of the void which is the minute crack in the fracture surface and directly under the fracture surface was dependent on the magnitude of balling-up carbide. although it is in the inclination for balling-up carbide to become detailed when the rate of balling-up is made small -- the decline in the rate of balling-up -- responding -- carbide distribution -- an ununiformity ---izing -- the blanking side between components -- a mold life also becomes short while variation becomes large at description. Conversely, at the big rate of balling-up, big and rough carbide comes to distribute and a minute crack and a void also become large. Then, the rate of balling-up of carbide and the mean diameter of balling-up carbide investigated the quantitive effect affect a minute crack and a void. the carbide which is in the observation visual field of a steel plate cross section -- maximum length -- the direction which intersects perpendicularly with p and the maximum length -- maximum length -- the ratio (p/q) of q treated less than three carbide as carbide which spheroidized, and it carried out comparatively the number of the balling-up carbide to all carbide, and asked for the rate of balling-up. Moreover, it **(ed) with the number of all the balling-up carbide that measured the sum total of the projected area diameter computed from the area of each balling-up carbide in the observation visual field of a steel plate cross section, and the acquired value was made into the mean particle diameter of balling-up carbide.
[0018] consequently -- if the rate of balling-up becomes 50% or more -- a blanking side -- ununiformity distribution of the carbide which makes description generate variation was canceled, and it turned out that a mold life also becomes long. However, at the rate of balling-up exceeding 95%, distribution of big and rough carbide is detected and the void and minute crack to generate also become large. Moreover, the void and the minute crack were made big and rough when the mean particle diameter of balling-up carbide exceeded 0.3 micrometers, and it turned out that the origin of a fatigue crack is easy to come. Big carbide remains with un-

dissolving at the time of heat treatment, and also becomes the cause of degrading the toughness after heat treatment. This point and balling-up carbide are so desirable that they are small, and are adjusted to 0.3 micrometers or less (suitably 0.2 micrometers or less) with mean particle diameter.

[0019] Hardness: When the hardness of 200 - 400HV steel materials runs short, the local deformation near the fracture surface increases at the time of blanking, and the inclination which the big void which is easy to become the origin of a fatigue crack as a result, and a minute crack generate is shown. The effect the lack of hardness affects the magnitude of a void or a minute crack appears notably in less than 200 HV. The lack of on the strength also becomes the cause which enlarges burr of a blanking side. However, in the hardness exceeding 400HV, the load to blanking metal mold becomes large, and shortens a mold life. The hardness of steel materials is influenced by the gestalt of carbide, and changes according to annealing conditions. Moreover, modification of the rate of cold rolling can also adjust hardness. As long as hardness is maintained in the range of 200 - 400HV, the constraint according to rank does not join the adjustment approach of hardness, and it is suitably adjusted by combination with annealing or cold rolling.

[0020] the steel plate with which the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and balling-up carbide were adjusted as mentioned above was excellent -- piercing -- workability -- presenting -- a good blanking side -- description is maintained. The temper of the pierced steel plate is carried out to the high intensity of 45 or more HRCs if needed. Although hardening or hardening, and annealing are common as the heat treatment approach for a temper, depending on an ingredient, isothermal treatment, such as austempering and martempering, is also employable. Improvement in a fatigue property can be aimed at and shot peening can also be carried out after heat treatment. Although fatigue strength generally becomes high according to the rise of material strength, if level on the strength is set to 45 or more HRCs, the susceptibility over the surface discontinuity of an ingredient will become high, and a rise on the strength will not necessarily be connected with an improvement of fatigue strength. That is, with the components as which high fatigue strength is required with a blanking side, it will pierce, if level on the strength is set to 45 or more HRCs, and the description of a field does big effect. the blanking side where the steel plate according to this point and this invention is good -- since it has description, the fatigue property which was excellent even if level on the strength was set to 45 or more HRCs is maintained.

[0021]

[Example] Steel with the presentation of Table 1 was ingoted with the converter, and continuous casting was carried out to slab. The obtained continuous casting slab was rolled round, it hot-rolled at the temperature of 600 degrees C, and the hot-rolling steel strip of 2.6mm of board thickness was manufactured. Acid washing of the hot-rolling steel strip was carried out, annealing and cold rolling were performed under the conditions of Table 2, and it was made the cold-rolled steel strip of 1.3mm of board thickness, adjusting hardness.

[0022]

表１：供試材の化学成分

鋼種記号	合金成分及び含有量 (重量%)																区分
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	V	Nb	Ti	B	Sol. Al	Insol. Al	N	O	
A	0.17	0.31	0.88	0.008	0.004	1.25	0.51	1.27	0.15	0.23	tr	tr	tr	0.049	0.004	0.0042	0.0032	比較例
B	0.89	1.94	1.72	0.008	0.007	2.57	0.23	1.88	0.38	0.16	tr	tr	tr	0.038	0.003	0.0020	0.0084	
C	0.61	1.05	0.49	0.009	0.014	0.53	0.84	0.86	0.11	tr	tr	tr	tr	0.055	0.004	0.0061	0.0111	
D	0.52	0.77	1.26	0.007	0.006	0.78	tr	tr	tr	tr	tr	tr	tr	0.062	0.003	0.0037	0.0023	本発明例
E	0.70	2.33	1.35	0.012	0.005	1.62	0.75	tr	0.34	tr	0.06	tr	tr	0.044	0.003	0.0057	0.0016	
F	0.43	0.28	1.14	0.006	0.004	1.15	0.33	0.76	0.21	0.05	tr	tr	tr	0.035	0.003	0.0055	0.0014	
G	0.54	0.06	0.17	0.008	0.004	0.21	tr	tr	0.05	tr	tr	tr	tr	0.042	0.003	0.0044	0.0018	
H	0.58	1.30	0.65	0.007	0.003	0.94	0.15	2.13	0.13	0.13	0.05	0.03	0.003	0.038	0.004	0.0065	0.0020	

下線は、本発明で規定した範囲を外れることを示す。

[0023]

表２：焼なまし及び冷間圧延条件

試験番号	鋼種記号	初回焼なまし条件		冷間圧延率 %	最終焼なまし条件		区分
		温度 ℃	時間 時		温度 ℃	時間 時	
1	A	700	12	50	670	7	比較例
2	B	670	7	50	620	7	
3	C	670	12	50	650	7	
4	D	700	12	50	620	7	本発明例
5	E	650	12	50	650	7	
6	F	650	12	50	600	7	
7	G	670	12	50	650	7	
8	H	700	12	50	670	7	
9	F	730	12	50	650	7	比較例
10	F	690	12	50	690	7	
11	F	650	12	50	520	7	
12	F	600	12	50	600	7	

下線は、本発明で規定した範囲を外れることを示す。

[0024] Each obtained piece of a cold-rolled steel strip blank test was started, and the mean particle diameter and hardness of the rate of carbide balling-up and balling-up carbide were measured. Moreover, the blanking side of the test piece pierced and processed was observed, and the void and minute crack near the fracture surface were investigated. And the magnitude of a void and a minute crack was computed by the sum total of the opening area of the crack occupied in unit observation area and the area of a void having carried out comparatively. Results of an investigation are shown in Table 3.

[0025]

表3：供試材の球状化率，平均球状化炭化物粒径，硬さ及び打抜き特性

試験番号	鋼種記号	炭化物の球状化率 %	球状化炭化物の平均粒径 μm	硬さ Hv	クラック・ボイド面積率 %	区分
1	A	90	0.25	208	0.7	比較例
2	B	71	0.12	353	1.5	
3	C	83	0.18	292	1.0	
4	D	88	0.24	276	1.2	本発明例
5	E	85	0.07	331	0.8	
6	F	67	0.05	375	0.3	
7	G	81	0.19	258	1.1	
8	H	93	0.23	219	1.3	
9	F	98	0.45	251	4.7	比較例
10	F	87	0.25	177	5.3	
11	F	72	0.06	434	0.2	
12	F	39	0.03	345	(0.9)	

下線は、本発明で規定した範囲を外れることを示す。
試験番号 12 のクラック・ボイド面積率は、ばらつきが大きいため参考値で示す。

[0026] Furthermore, after heating each cold-rolled steel strip at 850 degrees C for 15 minutes, it hardens and returned to 300 degrees C for 100 minutes. Each piece of a cold-rolled steel strip blank test after heat treatment was started, and hardness, tensile strength, and a fatigue property were investigated. In a fatigue characteristic test, the test piece which opened the circular hole with a diameter of 10mm in the center section by single-sided path clearance 10% blanking in 30mmx200mm size is used, a tension load is repeatedly added to a test piece by 20Hz with a hydraulic fatigue tester after heat treatment, and a fracture cycle is 105. The time amount reinforcement when becoming a time estimated the fatigue property. Results of an investigation are shown in Table 4.
[0027]

表４：各供試材の熱処理後の特性

試験番号	鋼種記号	硬さ HRC	引張強さ MPa	10^5サイクルの時間強度 MPa	区分
1	A	41.8	1297	428	比較例
2	B	54.1	1987	390	
3	C	52.4	1934	415	
4	D	51.6	1882	698	本発明例
5	E	55.8	2085	753	
6	F	50.2	1782	647	
7	G	48.3	1663	612	
8	H	54.3	2029	742	
9	F	48.5	1679	432	比較例
10	F	49.9	1780	411	
11	F	50.4	1788	654	
12	F	50.5	1791	428	

下線は、本発明で規定した範囲を外れることを示す。

[0028] Test numbers 1-3 (example of a comparison) have satisfied the conditions specified by this invention about the rate of carbide balling-up, the mean particle diameter of balling-up carbide, and hardness. However, the test number 1 with low C content runs short of reinforcement, and shows the value also with low fatigue strength. The test number 2 which contains C and Cr superfluously is MS. A point is low, and since it becomes an unstable organization containing retained austenite, although the hardness of 45 or more HRCs is secured, it shows the value with low fatigue strength. The example 3 of a comparison with many impurity contents, such as S and O, also shows the value with low fatigue strength, although the hardness of 45 or more HRCs is secured. Although test numbers 9-12 (example of a comparison) have satisfied the conditions specified by this invention in presentation, they are changing a carbide gestalt and hardness. With the test number 9 with the big mean diameter of balling-up carbide at 98%, the rate of carbide balling-up had the large rate of area of a void or a minute crack, and showed the value with low fatigue strength. The test number 10 which runs short of hardness also had the large rate of area of a void or a minute crack, and showed the value with low fatigue strength. Conversely, in the too hard test number 11, although the good fatigue property was shown, the life of blanking metal mold became extremely short. In the test number 12 with the low rate of balling-up of carbide, the description of the fracture surface destabilized and fatigue strength fell.

[0029] On the other hand, all, the test numbers 4-8 according to this invention had the small rate of area of a void or a minute crack, and had the fatigue strength which was excellent even when a temper was carried out to 45 or more HRCs. It is checked by combining the mean particle diameter and hardness of a quality governing, the rate of carbide balling-up, and balling-up carbide under specific conditions that the fatigue property which carried out the temper to high intensity and which pierced and was excellent also in components is acquired so that clearly from this contrast.

[0030]

[Effect of the Invention] As explained above, the steel plate for blanking components of this invention combined the mean particle diameter and hardness of a quality governing, the rate of carbide balling-up, and balling-up carbide under specific conditions, and has lowered the void which is near the fracture surface of a blanking side and serves as an origin of a fatigue crack,

and the rate of area of a minute crack. Therefore, even when a temper is carried out to the high intensity of 45 or more HRCs, the blanking components with which the outstanding fatigue property was given are obtained. Thus, the steel plate according to this invention fits the application as which a fatigue property is required with high intensity, and is used in a field extensive as various machine parts, a spring, a cutter, etc.

[Translation done.]

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TECHNICAL FIELD

[Industrial Application] This invention can carry out a temper to the high intensity of 45 or more HRCs in heat treatment after blanking processing, and relates to the steel plate used as various machine parts, such as a cutter, a tool, and a gearing, etc.

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PRIOR ART

[Description of the Prior Art] As a steel plate used for various machine parts etc., after piercing steel materials to a part shape, there are some a temper is carried out [some] by heat treatment. There are a high degree of hardness, high intensity, high toughness, high fatigue strength, abrasion resistance, etc. in the mechanical property required of this kind of components. A fatigue property and abrasion resistance improve by generally raising hardness and reinforcement. However, toughness falls with the rise of hardness or reinforcement and the defect resulting from especially the rise of notch susceptibility actualizes.
[0003] Notch susceptibility is ingredient physical properties which show generating inclinations, such as a crack on the basis of surface discontinuity etc., and fracture. Although the fracture surface is exposed to a steel-materials end face in the usual blanking processing, it is carried into a product, without removing completely surface discontinuity, such as a minute crack which exists in the fracture surface. The surface discontinuity which exists in the components end face after a punch acts as a notch or an initial crack, and becomes the cause which makes notch susceptibility of components high. Especially, in order to attain high intensity-ization of components, in 45 or more HRCs or tensile strength, with the steel materials raised to 1500 or more MPas, notch susceptibility becomes still higher and fatigue strength and toughness tend to fall temper hardness. the time of being based on the approach of creating components by machining, the approach of carrying out grinding of the end face of blanking components by machining, etc. -- a blanking side -- the effect of description is cancelable. However, these approaches have low productivity and are not suitable for components manufacture of a complicated configuration. Although it is also possible to remove the effect of a blanking side by polish, time amount and cost start by the grinding method. the blanking side in mass-production-method Rhine industrial from such a thing -- the guarantee of description is very difficult.
[0004]

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EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, the steel plate for blanking components of this invention combined the mean particle diameter and hardness of a quality governing, the rate of carbide balling-up, and balling-up carbide under specific conditions, and has lowered the void which is near the fracture surface of a blanking side and serves as an origin of a fatigue crack, and the rate of area of a minute crack. Therefore, even when a temper is carried out to the high intensity of 45 or more HRCs, the blanking components with which the outstanding fatigue property was given are obtained. Thus, the steel plate according to this invention fits the application as which a fatigue property is required with high intensity, and is used in a field extensive as various machine parts, a spring, a cutter, etc.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] The fracture surface becomes the origin of fatigue breaking among the fracture surface which constitutes a blanking side, and a shear plane. then, the thing for which the rate of a shear plane is raised -- piercing -- a field -- the method of improving description is adopted partly (JP,8-337843,A). Although the rate of a shear plane is raised even to 100% by fine blanking, use of the elasticity-ized ingredient is needed for the improvement of fine-blanking nature (JP,5-14764,B). However, since productivity and the yield are low as compared with the usual blanking, fine blanking is inapplicable to manufacture of cheap components from profit in many cases. Although the effect elasticity-ization affects the rise of the rate of a shear plane produces the usual blanking similarly, with the elasticity-ized ingredient, burr is large and the display flatness of the pierced components becomes low. There is a limitation in the improvement of this point and the blanking nature by elasticity-izing. The fall of components on the strength is also effective in an improvement of notch susceptibility. However, since fatigue strength also falls with a fall on the strength, the property required of various machine parts is not acquired.
[0005] Thus, it is difficult to raise a fatigue property, securing the reinforcement of blanking components, and it very difficult to pierce with the hardness level of 45 or more HRCs, and to improve the fatigue property of components especially. Furthermore, as a steel plate for blanking components, it is also required the components with which it heat-treats after a punch, and to excel in hardenability, the toughness after heat treatment, etc. from a certain thing. By being thought out that such a problem should be solved and combining the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and balling-up carbide under specific conditions, this invention is excellent in a fatigue property, and even if it carries out a temper to 45 or more HRCs after blanking processing, it aims at offering the usable steel plate for blanking components.

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MEANS

[Means for Solving the Problem] In order that the steel plate for blanking components of this invention may attain the purpose, C: 0.3 - 0.8 % of the weight, Si: 3.0 or less % of the weight, Mn: Less than [Cr:2.0 % of the weight], less than [Cu:0.5 % of the weight], N:0.0005 - 0.02 % of the weight, O:0.0005 - 0.01 % of the weight, P:0.02 % of the weight or less, S:0.01 % of the weight or less, and acid soluble aluminum:0.01-0.1 % of the weight are included 1.5 or less % of the weight. The remainder has the presentation of Fe substantially and the rate of balling-up of carbide is characterized by the mean particle diameter of balling-up carbide being [0.3 micrometers or less and hardness] 200 - 400HV 50 to 95%. This steel plate for blanking components can contain Mo:0.1-2.0 % of the weight, nickel:0.1-3.0 % of the weight, V:0.01 - 0.5 % of the weight, Ti:0.01-0.1 % of the weight, Nb:0.01-0.2 % of the weight, and B:0.0005 - 0.01% of the weight of one sort, or two sorts or more further.

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OPERATION

[Function] in order that this invention person etc. may suppress the effect the description of the fracture surface affects a fatigue property on the assumption that the fracture surface is generated in a blanking side to the minimum -- a blanking side -- investigation examination of the relation between description and a fatigue property was carried out at the detail. Consequently, when the ingredient which enlarged balling-up carbide and elasticity-ized it was pierced, while the rate of a shear plane of a blanking side became high, it found out that the dimension of the void in the minute crack and directly under [fracture surface] was large. [in the fracture surface] On the other hand, when carbide was made small and a certain amount of hardness was given to steel materials, it solved that the minute crack and void used as the origin of fatigue breaking were stopped to the minimum.
[0008] The effect the magnitude of carbide affects a minute crack and a void is considered as follows. Although the trace with which carbide was dragged by the local plastic deformation at the time of blanking remains near the fracture surface, extent of a trace differs according to the magnitude of carbide, and the minute crack by which a big and rough void and a big and rough void gathered and grew arises in an organization with big and rough carbide. Moreover, the steel materials of elasticity [migration length / of the carbide dragged at the time of blanking] become long, and a void and a minute crack become large according to the die length of migration length. It is necessary to carry out the temper of the steel materials to a certain amount of hardness, and to control the migration length of carbide at this point. Although the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and balling-up carbide are combined under specific conditions by this invention by using the above knowledge as the base, it explains for every requirements below.
[0009] It is the fundamental alloy content which affects the reinforcement and the toughness of the C:0.3 - 0.8 % of the weight steel materials of quality governings, and in order to obtain the hardness of 45 or more HRCs, 0.3 % of the weight or more is needed. however, the void which the amount of increment ****** carbide of C content increases, and originates in carbide is quantitative -- and it becomes large in size. Moreover, in C content exceeding 0.8 % of the weight, a cementite deposits in a grain boundary and toughness and fatigue strength worsen. C content of an excessive amount is MS. The fall of strength, toughness, and a fatigue property is caused for the generation inclination of retained austenite by the fall of a point.
Si: It is the alloy content added by molten steel as a deoxidizer 3.0 or less % of the weight, and raise hardenability and it is effective also as a solid-solution-strengthening element of a ferrite. The operation which delays a deposit of the carbide at the time of heat treatment is presented, and it also becomes the cause of producing internal oxidation directly under a steel-materials front face in the cases, such as hot-rolling, annealing, and heat treatment. Moreover, Si addition of an excessive amount makes steel materials hard, and enlarges the burden to blanking metal mold. In order to control these bad influences, the upper limit of Si content was set up to 3.0% of the weight. In addition, since deoxidation of molten steel is compensated of

other components, such as Mn and aluminum, it can also consider as Si additive-free fundamentally.

[0010] Mn: It is the alloy content added by molten steel as a deoxidizer 1.5 or less % of the weight, and act effective also in improvement in hardenability. However, at the time of blanking, the nonmetallic inclusion of Mn system used as the origin of a void or a minute crack is generated, and the bad influence which causes the toughness fall by development of the band structure is also done. Moreover, Mn addition of an excessive amount makes steel materials hard, and enlarges the burden to blanking metal mold. In order to control these bad influences, the upper limit of Mn content was set up to 1.5% of the weight. In addition, since deoxidation of molten steel is compensated of other components, such as Si and aluminum, it can also consider as Mn additive-free fundamentally.

Cr: It is an alloy content effective in improvement in the reinforcement after 2.0 or less % of the weight hardenability and heat treatment, and toughness, and also present the operation which prevents graphitization during annealing. However, if Cr of the excessive amount exceeding 2.0 % of the weight is contained, while the fall of toughness will be seen on the contrary and balling-up annealing will become difficult, the manufacturability of an intermediate product also deteriorates. Cr addition of an excessive amount makes steel materials hard, and also enlarges the burden to blanking metal mold. Since hardenability, and the reinforcement and the toughness after heat treatment are suppliable with other alloy contents, it can also consider as Cr additive-free fundamentally.

[0011] Cu: It is an alloy content effective when improving the hardenability of steel materials, and the toughness after heat treatment like nickel 0.5 or less % of the weight. However, Cu addition of the excessive amount exceeding 0.5 % of the weight becomes the cause which causes hot shortness.

V, aluminum, Ti, Nb, etc. a nitride, and carbon nitride are formed N:0.0005 to 0.02% of the weight, it is the alloy content which presents the operation which makes an austenite grain detailed, and when compound addition is carried out with these elements, the effectiveness of N becomes remarkable with 0.0005% of the weight or more of a content. However, if N of the excessive amount exceeding 0.02 % of the weight is contained, detailed-ized effectiveness is not only saturated, but the bad influence to which toughness and a fatigue property are reduced on the contrary will appear.

[0012] O:0.0005 - 0.01-% of the weight aluminum 2O3 etc. – it is the injurious ingredient which forms nonmetallic inclusion. Nonmetallic inclusion may become the origin of a fatigue crack by the nonmetallic inclusion itself while becoming the origin of a void or a minute crack at the time of blanking. Moreover, since the toughness after hardening / annealing was reduced and it had the bad influence also on the fatigue property, the upper limit of O content was set up to 0.01% of the weight. Although the lowest possible O content was desirable, since reduction of extreme O content made the manufacturing cost rise, the minimum of O content was set up to 0.0005% of the weight.

It is the injurious ingredient to which it segregates to the grain boundary P:0.02 or less % of the weight, and the toughness after hardening / annealing is reduced, and decreasing as much as possible is desirable. However, according to reduction of P content, a manufacturing cost becomes high. Then, the range which does not have a substantial bad influence on toughness degradation was investigated, and the upper limit of P content was set up to 0.02% of the weight.

[0013] It is the injurious ingredient which forms nonmetallic inclusion, such as MnS, S:0.01 or less % of the weight, and has a bad influence on the workability of steel materials, reinforcement, and toughness. MnS serves as an origin of a void or a minute crack at the time of blanking, and the MnS itself becomes the origin of a fatigue crack. Moreover, in the rolled stock by which MnS is spread by the rolling direction, plane anisotropy appears greatly in

workability, reinforcement, and toughness. In order to control these bad influences, the upper limit of S content was set up to 0.01% of the weight.
Acid Meltable aluminum: 0.01 to 0.1% of the weight, aluminum is an effective alloy content as a deoxidizer, fix N in steel as AlN, and also present the operation which controls abnormality growth of austenite crystal grain at the time of heat treatment. These operations become remarkable at 0.01 % of the weight or more as acid meltable aluminum. However, the effectiveness of acid meltable aluminum is saturated with 0.1 % of the weight, and acid meltable aluminum of an excessive amount causes defective generating, such as a rise of a manufacturing cost, and a surface crack, on the contrary.
[0014] Mo: It is the alloy content added if needed 0.1 to 2.0% of the weight, and present the operation which raises hardenability, and the reinforcement and the toughness after heat treatment. Such effectiveness becomes remarkable with 0.1% of the weight or more of Mo content. However, if Mo of the excessive amount exceeding 2.0 % of the weight is contained, while toughness will fall on the contrary and balling-up annealing will become difficult, the manufacturability of an intermediate product deteriorates remarkably. Mo of an excessive amount makes steel materials hard remarkably, and also enlarges the burden to blanking metal mold.
nickel: It is the alloy content added if needed 0.1 to 3.0% of the weight, and present the operation which raises hardenability and the toughness after heat treatment. Moreover, since reinforcement and toughness improve by nickel addition, a fatigue property is also improved. Such effectiveness becomes remarkable with 0.1% of the weight or more of nickel content. The effectiveness of nickel which raises the reinforcement after heat treatment, toughness, and crack propagation resistance is saturated with 3.0 % of the weight, with nickel of the excessive amount exceeding 3.0 % of the weight, steel materials make it hard remarkably and the burden to blanking metal mold also becomes large.
[0015] It is the alloy content added if needed V:0.01 to 0.5% of the weight, and while forming carbide in steel and raising reinforcement and toughness, the operation which makes the old austenite crystal grain detailed and raises crack propagation resistance is presented. Although such an operation and effectiveness become remarkable with 0.01% of the weight or more of V content, reinforcement, toughness, and the effectiveness of raising crack propagation resistance are saturated with 0.5 % of the weight. If V of the excessive amount exceeding 0.5 % of the weight is contained, the manufacturability of an intermediate product will deteriorate on the contrary.
Ti: It is the alloy content added if needed 0.01 to 0.1% of the weight, and form the carbon nitride which cannot dissolve easily at the time of heat treatment, control big and rough-ization of the austenite crystal grain at the time of hardening heating, and present the operation which raises crack propagation resistance. In compound addition with B, since N in steel is fixed as TiN, it works to also secure the amount of effective B. An operation of such Ti becomes remarkable at 0.01 % of the weight or more. However, Ti content of the excessive amount exceeding 0.1 % of the weight becomes the cause that a big and rough nitride is formed, and causes the fall of toughness.
[0016] Nb: It is the alloy content added if needed 0.01 to 0.2% of the weight, and form stable carbon nitride, control big and rough-ization of crystal grain like V and Ti at the time of hardening, and present the operation which prevents degradation of toughness. Such an operation becomes remarkable with 0.01% of the weight or more of Nb content. However, Nb of the excessive amount exceeding 0.2 % of the weight decreases the dissolution of carbide to a matrix, and causes a fall on the strength.
It is the alloy content added if needed B:0.0005 to 0.01% of the weight, and hardenability is raised, the segregation of P to the grain boundary is controlled, the grain boundary is strengthened, and the operation which prevents the toughness fall resulting from intergranular

fracture is presented. Although such an operation becomes remarkable with 0.0005% of the weight or more of B content, it is saturated with 0.01 % of the weight. In addition, since the effectiveness of B addition will be spoiled if added B combines with N in steel and becomes Nitride BN, it is desirable to carry out compound addition of Ti which fixes N in steel as TiN on the occasion of B addition.

[0017] rate [of carbide] of balling-up: -- the gestalt of the mean-particle-diameter:0.3-micrometer or less carbide of 50 - 95%, and balling-up carbide -- the fracture surface of blanking workability and a blanking side -- it has big effect on description. The investigation and research by this invention person etc. showed that the magnitude of the void which is the minute crack in the fracture surface and directly under the fracture surface was dependent on the magnitude of balling-up carbide. although it is in the inclination for balling-up carbide to become detailed when the rate of balling-up is made small -- the decline in the rate of balling-up -- responding -- carbide distribution -- an ununiformity ---izing -- the blanking side between components -- a mold life also becomes short while variation becomes large at description. Conversely, at the big rate of balling-up, big and rough carbide comes to distribute and a minute crack and a void also become large. Then, the rate of balling-up of carbide and the mean diameter of balling-up carbide investigated the quantitive effect affect a minute crack and a void. the carbide which is in the observation visual field of a steel plate cross section -- maximum length -- the direction which intersects perpendicularly with p and the maximum length -- maximum length -- the ratio (p/q) of q treated less than three carbide as carbide which spheroidized, and it carried out comparatively the number of the balling-up carbide to all carbide, and asked for the rate of balling-up. Moreover, it **(ed) with the number of all the balling-up carbide that measured the sum total of the projected area diameter computed from the area of each balling-up carbide in the observation visual field of a steel plate cross section, and the acquired value was made into the mean particle diameter of balling-up carbide.

[0018] consequently -- if the rate of balling-up becomes 50% or more -- a blanking side -- ununiformity distribution of the carbide which makes description generate variation was canceled, and it turned out that a mold life also becomes long. However, at the rate of balling-up exceeding 95%, distribution of big and rough carbide is detected and the void and minute crack to generate also become large. Moreover, the void and the minute crack were made big and rough when the mean particle diameter of balling-up carbide exceeded 0.3 micrometers, and it turned out that the origin of a fatigue crack is easy to come. Big carbide remains with un-dissolving at the time of heat treatment, and also becomes the cause of degrading the toughness after heat treatment. This point and balling-up carbide are so desirable that they are small, and are adjusted to 0.3 micrometers or less (suitably 0.2 micrometers or less) with mean particle diameter.

[0019] Hardness: When the hardness of 200 - 400HV steel materials runs short, the local deformation near the fracture surface increases at the time of blanking, and the inclination which the big void which is easy to become the origin of a fatigue crack as a result, and a minute crack generate is shown. The effect the lack of hardness affects the magnitude of a void or a minute crack appears notably in less than 200 HV. The lack of on the strength also becomes the cause which enlarges burr of a blanking side. However, in the hardness exceeding 400HV, the load to blanking metal mold becomes large, and shortens a mold life. The hardness of steel materials is influenced by the gestalt of carbide, and changes according to annealing conditions. Moreover, modification of the rate of cold rolling can also adjust hardness. As long as hardness is maintained in the range of 200 - 400HV, the constraint according to rank does not join the adjustment approach of hardness, and it is suitably adjusted by combination with annealing or cold rolling.

[0020] the steel plate with which the magnitude and the hardness level of a quality governing, the rate of balling-up of carbide, and balling-up carbide were adjusted as mentioned above

was excellent – piercing – workability – presenting – a good blanking side – description is maintained. The temper of the pierced steel plate is carried out to the high intensity of 45 or more HRCs if needed. Although hardening or hardening, and annealing are common as the heat treatment approach for a temper, depending on an ingredient, isothermal treatment, such as austempering and martempering, is also employable. Improvement in a fatigue property can be aimed at and shot peening can also be carried out after heat treatment. Although fatigue strength generally becomes high according to the rise of material strength, if level on the strength is set to 45 or more HRCs, the susceptibility over the surface discontinuity of an ingredient will become high, and a rise on the strength will not necessarily be connected with an improvement of fatigue strength. That is, with the components as which high fatigue strength is required with a blanking side, it will pierce, if level on the strength is set to 45 or more HRCs, and the description of a field does big effect. the blanking side where the steel plate according to this point and this invention is good – since it has description, the fatigue property which was excellent even if level on the strength was set to 45 or more HRCs is maintained.

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EXAMPLE

[Example] Steel with the presentation of Table 1 was ingoted with the converter, and continuous casting was carried out to slab. The obtained continuous casting slab was rolled round, it hot-rolled at the temperature of 600 degrees C, and the hot-rolling steel strip of 2.6mm of board thickness was manufactured. Acid washing of the hot-rolling steel strip was carried out, annealing and cold rolling were performed under the conditions of Table 2, and it was made the cold-rolled steel strip of 1.3mm of board thickness, adjusting hardness.
[0022]

表１：供試材の化学成分

鋼種記号	合金成分及び含有量 (重量%)																	区分
	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	V	Nb	Ti	B	Sol. Al	Insol. Al	N	O	
A	0.17	0.31	0.38	0.008	0.004	1.25	0.61	1.27	0.15	0.23	tr	tr	tr	0.049	0.004	0.0042	0.0032	比較例
B	0.89	1.94	1.72	0.008	0.007	2.57	0.23	1.38	0.38	0.16	tr	tr	tr	0.038	0.003	0.0020	0.0084	
C	0.61	1.05	0.49	0.009	0.014	0.53	0.84	0.86	0.11	tr	tr	tr	tr	0.055	0.004	0.0061	0.0111	
D	0.52	0.77	1.26	0.007	0.006	0.78	tr	tr	tr	tr	tr	tr	tr	0.062	0.003	0.0037	0.0023	本発明例
E	0.70	2.33	1.35	0.012	0.005	1.62	0.75	tr	0.34	tr	0.06	tr	tr	0.044	0.003	0.0057	0.0016	
F	0.43	0.28	1.14	0.006	0.004	1.15	0.33	0.76	0.21	0.05	tr	tr	tr	0.035	0.003	0.0055	0.0014	
G	0.54	0.06	0.17	0.008	0.004	0.21	tr	tr	0.05	tr	tr	tr	tr	0.042	0.003	0.0044	0.0018	
H	0.58	1.30	0.65	0.007	0.003	0.94	0.15	2.13	0.13	0.13	0.05	0.03	0.003	0.038	0.004	0.0065	0.0020	

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[0023]

表２：焼なまし及び冷間圧延条件

試験番号	鋼種記号	初回焼なまし条件		冷間圧延率 %	最終焼なまし条件		区分
		温度 ℃	時間 時		温度 ℃	時間 時	
1	A	700	12	50	670	7	比較例
2	B	670	7	50	620	7	
3	C	670	12	50	650	7	
4	D	700	12	50	620	7	本発明例
5	E	650	12	50	650	7	
6	F	650	12	50	600	7	
7	G	670	12	50	650	7	
8	H	700	12	50	670	7	
9	F	730	12	50	650	7	比較例
10	F	690	12	50	690	7	
11	F	650	12	50	520	7	
12	F	600	12	50	600	7	

下線は、本発明で規定した範囲を外れることを示す。

[0024] Each obtained piece of a cold-rolled steel strip blank test was started, and the mean particle diameter and hardness of the rate of carbide balling-up and balling-up carbide were measured. Moreover, the blanking side of the test piece pierced and processed was observed, and the void and minute crack near the fracture surface were investigated. And the magnitude of a void and a minute crack was computed by the sum total of the opening area of the crack occupied in unit observation area and the area of a void having carried out comparatively. Results of an investigation are shown in Table 3.

[0025]

表3：供試材の球状化率，平均球状化炭化物粒径，硬さ及び打抜き特性

試験番号	鋼種記号	炭化物の球状化率 %	球状化炭化物の平均粒径 μm	硬さ Hv	クラック・ボイド面積率 %	区分
1	A	90	0.25	208	0.7	比較例
2	B	71	0.12	353	1.5	
3	C	83	0.18	292	1.0	
4	D	88	0.24	276	1.2	本発明例
5	E	85	0.07	331	0.8	
6	F	67	0.05	375	0.3	
7	G	81	0.19	258	1.1	
8	H	93	0.23	219	1.3	
9	F	98	0.45	251	4.7	比較例
10	F	87	0.25	177	5.3	
11	F	72	0.06	434	0.2	
12	F	39	0.03	345	(0.9)	

下線は、本発明で規定した範囲を外れることを示す。
試験番号 12 のクラック・ボイド面積率は、ばらつきが大きいため参考値で示す。

[0026] Furthermore, after heating each cold-rolled steel strip at 850 degrees C for 15 minutes, it hardens and returned to 300 degrees C for 100 minutes. Each piece of a cold-rolled steel strip blank test after heat treatment was started, and hardness, tensile strength, and a fatigue property were investigated. In a fatigue characteristic test, the test piece which opened the circular hole with a diameter of 10mm in the center section by single-sided path clearance 10% blanking in 30mmx200mm size is used, a tension load is repeatedly added to a test piece by 20Hz with a hydraulic fatigue tester after heat treatment, and a fracture cycle is 105. The time amount reinforcement when becoming a time estimated the fatigue property. Results of an investigation are shown in Table 4.
[0027]

表４：各供試材の熱処理後の特性

試験番号	鋼種記号	硬さ HRC	引張強さ MPa	10^5サイクルの時間強度 MPa	区分
1	A	41.8	1297	428	比較例
2	B	54.1	1987	390	
3	C	52.4	1934	415	
4	D	51.6	1882	698	本発明例
5	E	55.8	2085	753	
6	F	50.2	1782	647	
7	G	48.3	1663	612	
8	H	54.3	2029	742	
9	F	48.5	1679	432	比較例
10	F	49.9	1780	411	
11	F	50.4	1788	654	
12	F	50.5	1791	428	

下線は、本発明で規定した範囲を外れることを示す。

[0028] Test numbers 1-3 (example of a comparison) have satisfied the conditions specified by this invention about the rate of carbide balling-up, the mean particle diameter of balling-up carbide, and hardness. However, the test number 1 with low C content runs short of reinforcement, and shows the value also with low fatigue strength. The test number 2 which contains C and Cr superfluously is MS. A point is low, and since it becomes an unstable organization containing retained austenite, although the hardness of 45 or more HRCs is secured, it shows the value with low fatigue strength. The example 3 of a comparison with many impurity contents, such as S and O, also shows the value with low fatigue strength, although the hardness of 45 or more HRCs is secured. Although test numbers 9-12 (example of a comparison) have satisfied the conditions specified by this invention in presentation, they are changing a carbide gestalt and hardness. With the test number 9 with the big mean diameter of balling-up carbide at 98%, the rate of carbide balling-up had the large rate of area of a void or a minute crack, and showed the value with low fatigue strength. The test number 10 which runs short of hardness also had the large rate of area of a void or a minute crack, and showed the value with low fatigue strength. Conversely, in the too hard test number 11, although the good fatigue property was shown, the life of blanking metal mold became extremely short. In the test number 12 with the low rate of balling-up of carbide, the description of the fracture surface destabilized and fatigue strength fell.

[0029] On the other hand, all, the test numbers 4-8 according to this invention had the small rate of area of a void or a minute crack, and had the fatigue strength which was excellent even when a temper was carried out to 45 or more HRCs. It is checked by combining the mean particle diameter and hardness of a quality governing, the rate of carbide balling-up, and balling-up carbide under specific conditions that the fatigue property which carried out the temper to high intensity and which pierced and was excellent also in components is acquired so that clearly from this contrast.

[Translation done.]